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**Kawana et al.**

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(54) **NUMERICAL CONTROL METHOD AND NUMERICAL CONTROL DEVICE OF MACHINE TOOL**

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***G06F 19/00*** (2011.01)
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(58) **Field of Classification Search**
USPC .................... 700/37, 28, 186–188, 173–177, 700/159–162; 318/632, 561, 569
See application file for complete search history.

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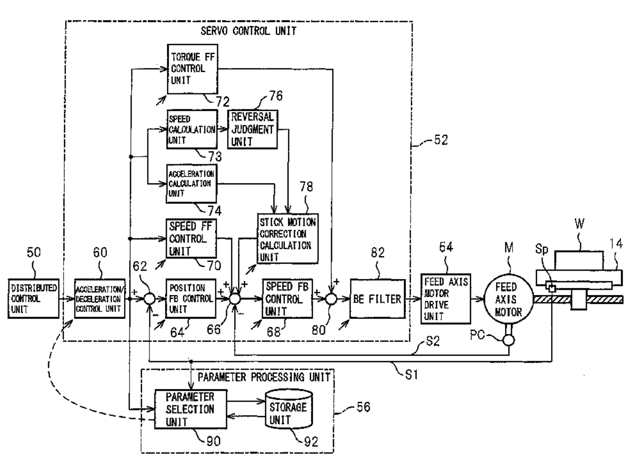
(57) **ABSTRACT**

A numerical control device which controls a feed axis of a machine tool has a storage unit which divides a range of movement of the feed axis into a plurality of regions and stores a plurality of control parameters corresponding to the divided plurality of regions in advance, a position detection unit which detects a position of a feed axis at the time of machining a workpiece, a parameter selection unit which reads out control parameters corresponding to a divided region to which the detected feed axis position at the time of machining a workpiece belongs, and a servo control unit which controls the feed axis using the read control parameters. Due to this, it is possible to provide a numerical control method of a machine tool which realizes stable machining precision without regard as to the feed axis position and a numerical control device which conducts that method.

**4 Claims, 8 Drawing Sheets**



(51) **Int. Cl.**
***G05B 13/00*** (2006.01)
***G05D 23/275*** (2006.01)
***G05B 19/404*** (2006.01)

(52) **U.S. Cl.**
CPC ................ *G05B2219/41083* (2013.01); *G05B 2219/41155* (2013.01); *G05B 2219/42039* (2013.01); *G05B 2219/49182* (2013.01)

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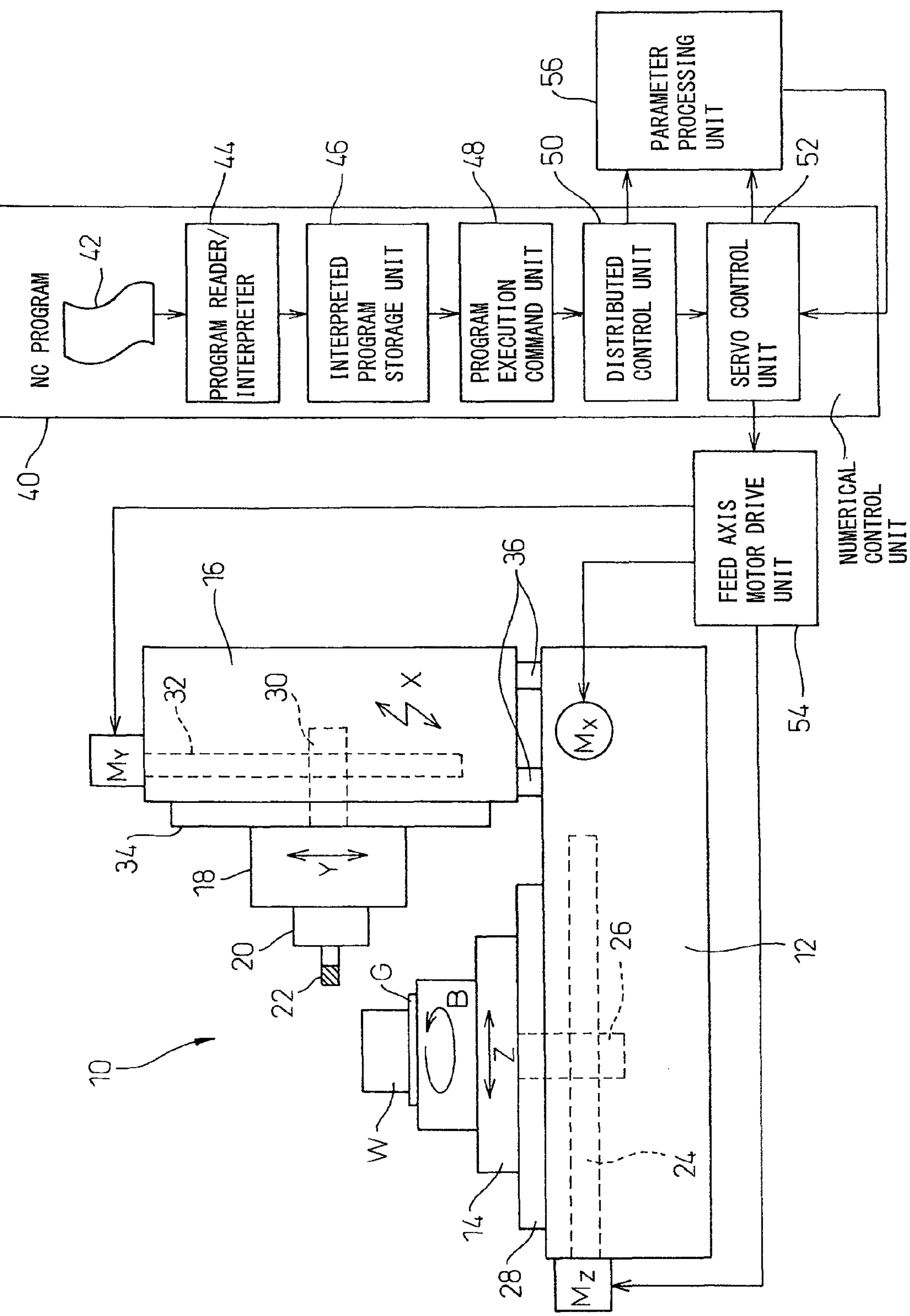
Fig. 1


NC PROGRAM
PROGRAM READER/ INTERPRETER
INTERPRETED PROGRAM STORAGE UNIT
PROGRAM EXECUTION COMMAND UNIT
DISTRIBUTED CONTROL UNIT
SERVO CONTROL UNIT
PARAMETER PROCESSING UNIT
FEED AXIS MOTOR DRIVE UNIT
NUMERICAL CONTROL UNIT
10
12
14
16
18
20
22
24
26
28
30
32
34
36
40
42
44
46
48
50
52
54
56
X
Y
Z
B
G
W
$M_X$
$M_Y$
$M_Z$

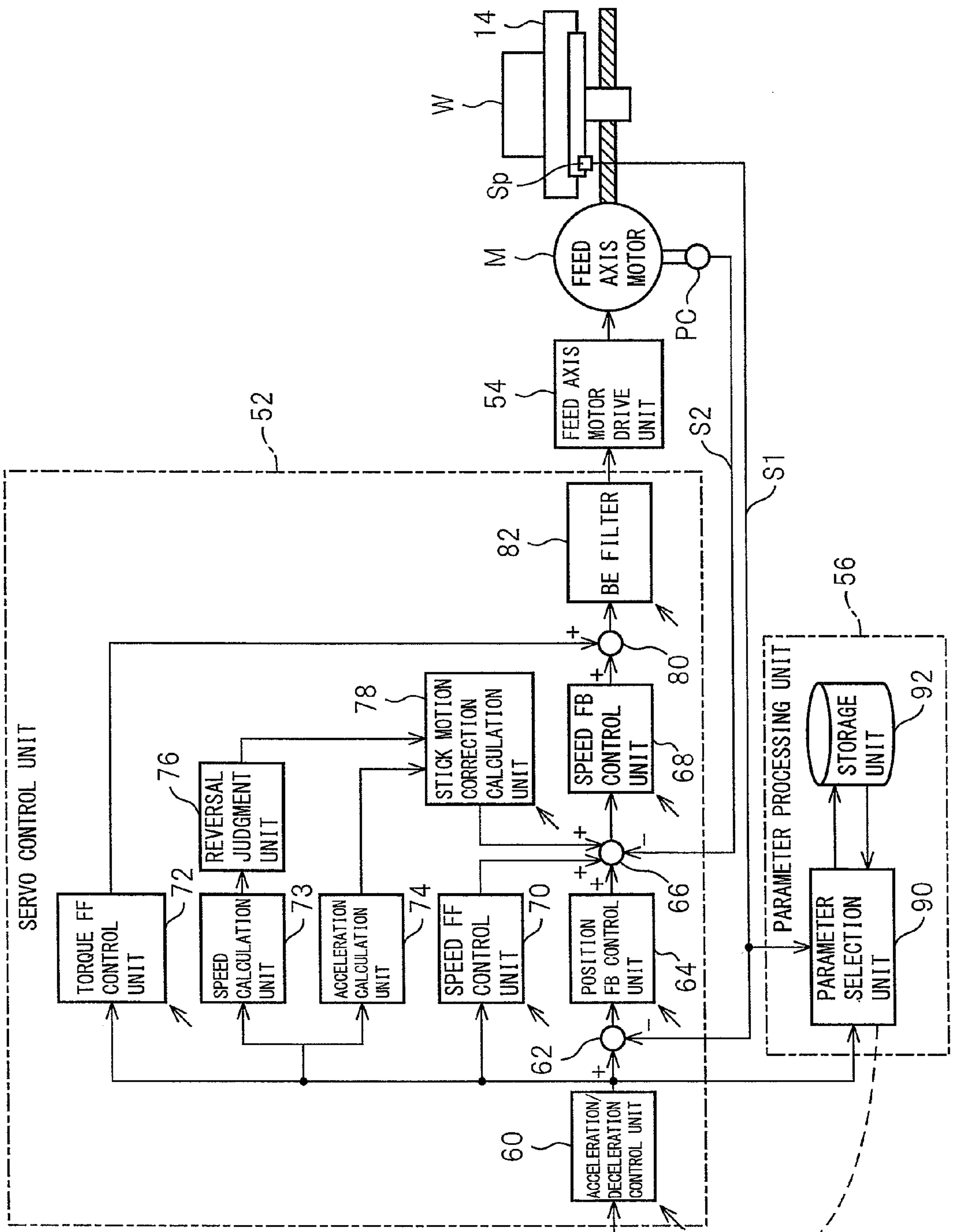

SERVO CONTROL UNIT
52
DISTRIBUTED CONTROL UNIT
50
ACCELERATION/DECELERATION CONTROL UNIT
60
TORQUE FF CONTROL UNIT
72
SPEED CALCULATION UNIT
73
ACCELERATION CALCULATION UNIT
74
SPEED FF CONTROL UNIT
70
POSITION FB CONTROL UNIT
64
62
66
REVERSAL JUDGMENT UNIT
76
STICK MOTION CORRECTION CALCULATION UNIT
78
SPEED FB CONTROL UNIT
68
80
BE FILTER
82
FEED AXIS MOTOR DRIVE UNIT
54
FEED AXIS MOTOR
M
PC
Sp
W
14
S1
S2
PARAMETER PROCESSING UNIT
56
PARAMETER SELECTION UNIT
90
STORAGE UNIT
92

Fig.2

Fig.3

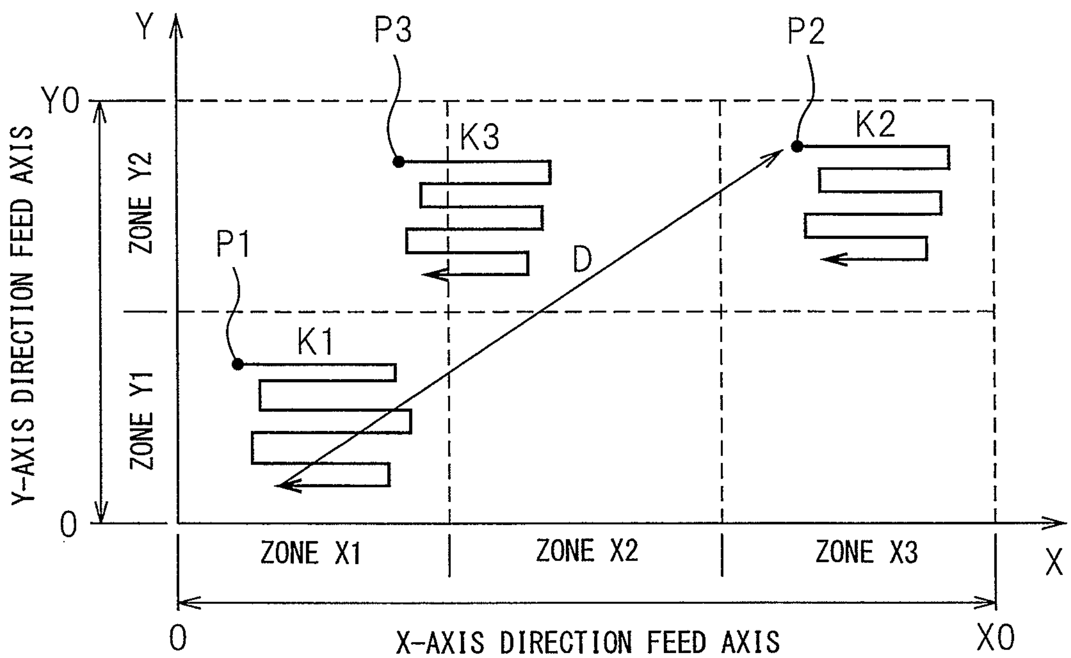
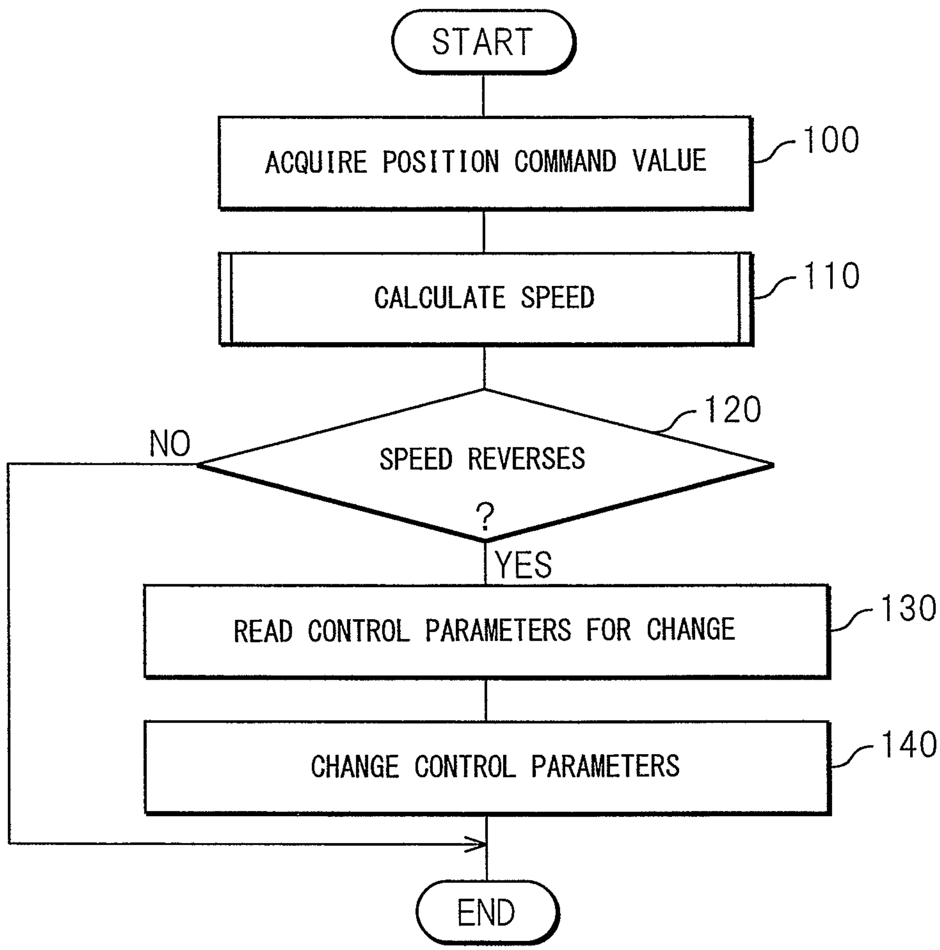

Y
P3
P2
Y0
K3
K2
Y-AXIS DIRECTION FEED AXIS
ZONE Y2
P1
D
K1
ZONE Y1
0
ZONE X1
ZONE X2
ZONE X3
X
0
X-AXIS DIRECTION FEED AXIS
X0

Fig.4


START
ACQUIRE POSITION COMMAND VALUE
100
CALCULATE SPEED
110
SPEED REVERSES ?
120
NO
YES
READ CONTROL PARAMETERS FOR CHANGE
130
CHANGE CONTROL PARAMETERS
140
END

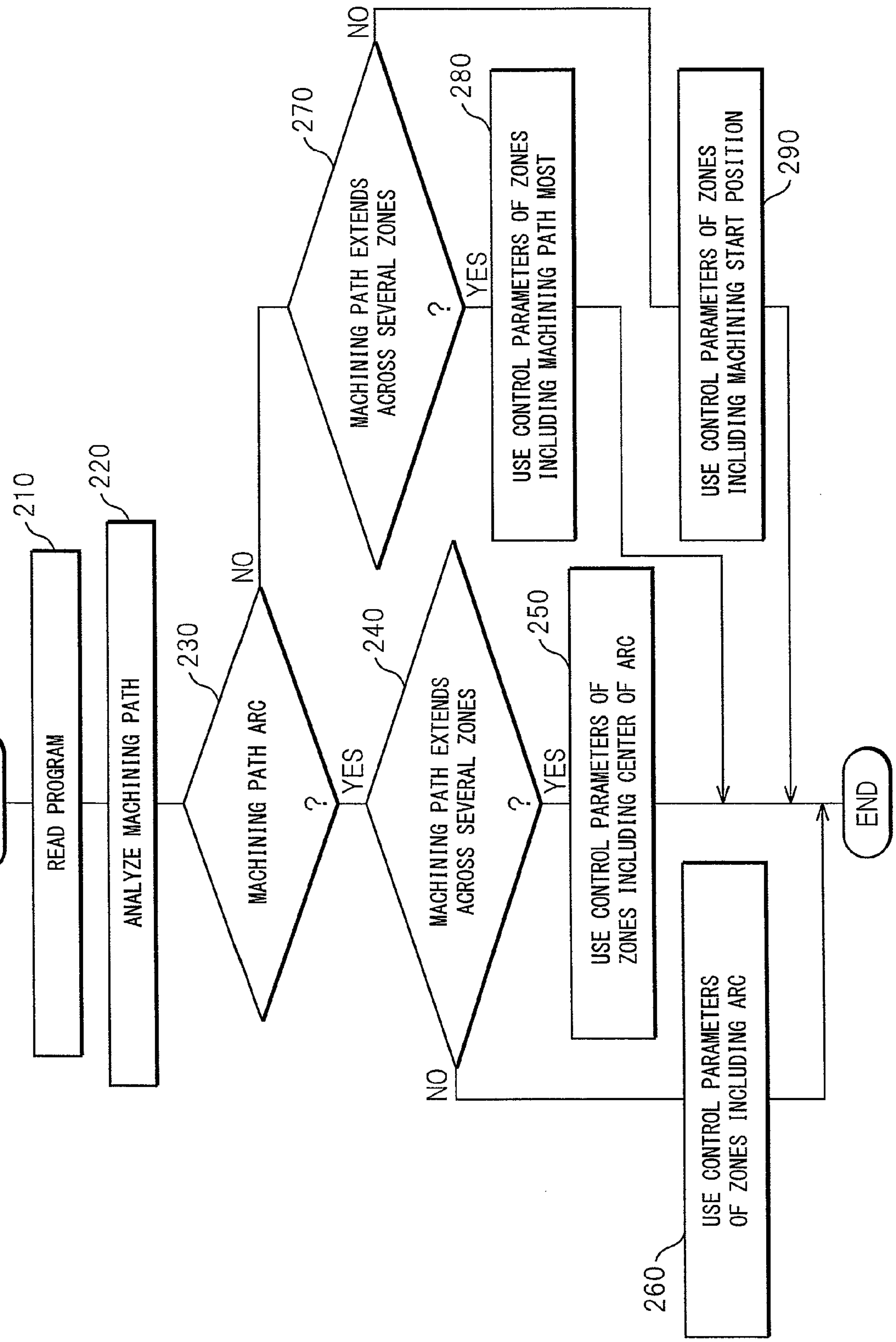

START
READ PROGRAM
210
ANALYZE MACHINING PATH
220
MACHINING PATH ARC ?
230
YES
NO
MACHINING PATH EXTENDS ACROSS SEVERAL ZONES ?
240
YES
NO
USE CONTROL PARAMETERS OF ZONES INCLUDING CENTER OF ARC
250
USE CONTROL PARAMETERS OF ZONES INCLUDING ARC
260
MACHINING PATH EXTENDS ACROSS SEVERAL ZONES ?
270
YES
NO
USE CONTROL PARAMETERS OF ZONES INCLUDING MACHINING PATH MOST
280
USE CONTROL PARAMETERS OF ZONES INCLUDING MACHINING START POSITION
290
END

Fig.5

Fig.6

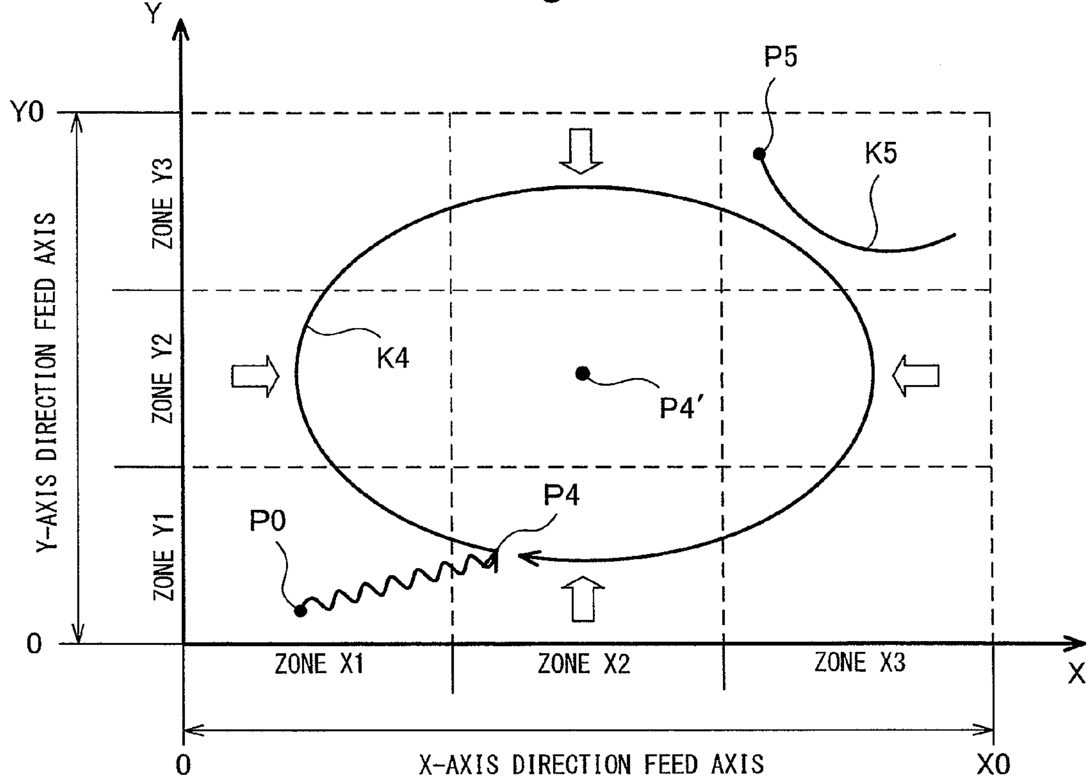

Y
Y0
P5
K5
ZONE Y3
ZONE Y2
ZONE Y1
Y-AXIS DIRECTION FEED AXIS
K4
P4′
P4
P0
0
ZONE X1
ZONE X2
ZONE X3
X
0
X-AXIS DIRECTION FEED AXIS
X0

Fig.7a

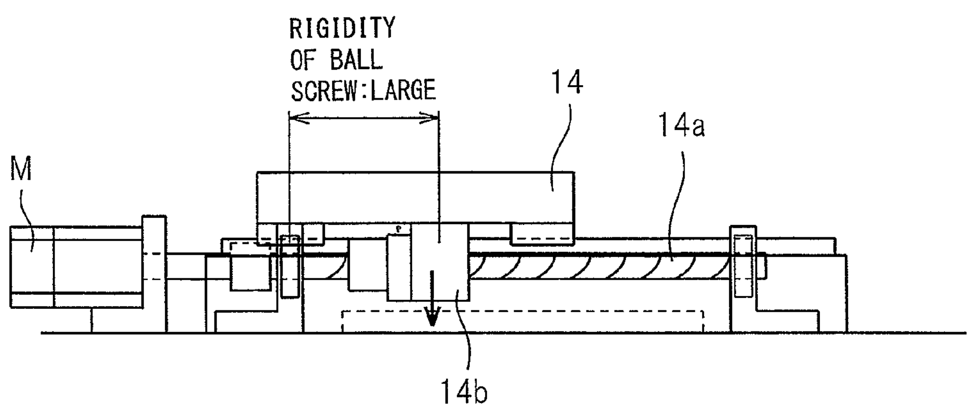

RIGIDITY
OF BALL
SCREW:LARGE
14
14a
M
14b

Fig.7b

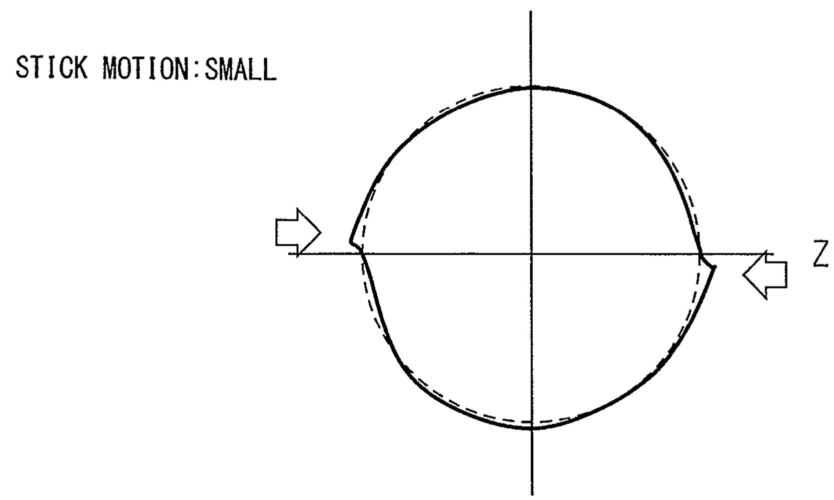

STICK MOTION:SMALL
Z

Fig.8a

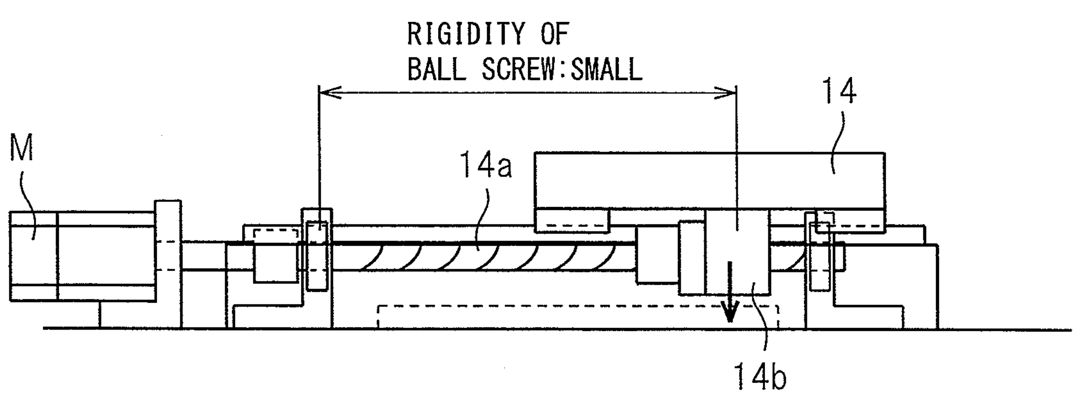

RIGIDITY OF
BALL SCREW:SMALL
14
M
14a
14b

Fig.8b

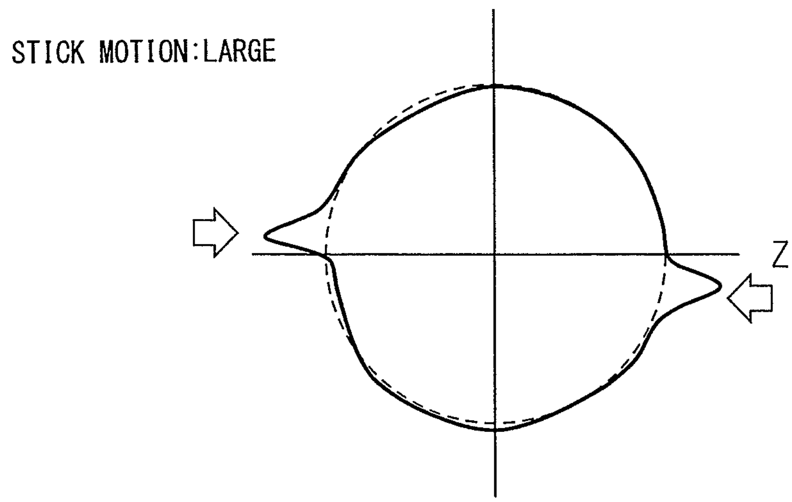
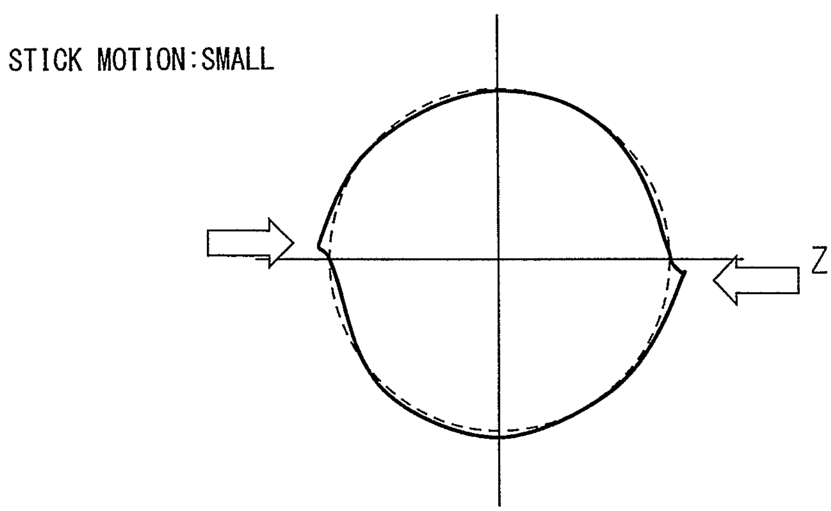



Fig.8c



# NUMERICAL CONTROL METHOD AND NUMERICAL CONTROL DEVICE OF MACHINE TOOL

## REFERENCE TO RELATED APPLICATIONS

This application is the national stage application under 35 USC 371 of International Application No. PCT/JP2011/074698, filed Oct. 26, 2011, which claims priority from Japanese Patent Application No. 2010-241388, filed Oct. 27, 2010, the entire contents of which are incorporated herein by reference.

## TECHNICAL FIELD OF THE INVENTION

The present invention relates to a numerical control method which controls a feed axis of a machine tool and a numerical control device which conducts that method.

## BACKGROUND OF THE INVENTION

A machine tool includes at least one feed mechanism for making a workpiece and a tool move relative to each other. The motor for driving the feed mechanism is controlled by a numerical control device. When a feed direction of the workpiece or tool is reversed by the feed mechanism, the direction of action of frictional force between the relatively moving parts included in the feed mechanism (for example, the feed screw and nut) reverses, so the phenomenon arises of the operation of the feed mechanism being delayed for an instant. For example, when using two perpendicularly intersecting linear feed mechanisms to make a workpiece or tool move in an arc, this phenomenon of delay generally causes the unpreferable position error called "stick motion".

In relation to this, there is known a numerical control device which is designed to update backlash correction command values in accordance with the elapsed time from the occurrence of reversal if the feed direction of the table carrying the workpiece reverses, to add the correction command values to the position command values, to use the results of addition as the basis to control operation of the servo motors which drive the table, to precisely compensate for elastic deformation which occurs when the feed direction reverses, and to suppress occurrence of stick motion (see PLT 1). Further, PLT 2 discloses to change the Y-axis servo parameters of speed loop gain and position loop gain in accordance with the X-axis position.

PLT 1: Japanese Unexamined Patent Publication No. 2004-234205A

PLT 2: Japanese Unexamined Patent Publication No. 6-297058A

## SUMMARY OF THE INVENTION

### Technical Problem

In this regard, a feed mechanism has a predetermined path of movement for the feed direction. A position on this path will hereinafter be referred to as a "feed axis position". For example, when the feed mechanism is comprised of a feed screw and nut, the position of the nut with respect to the feed screw corresponds to the "feed axis position". Depending on the feed axis position, the rigidity of the feed screw and the friction coefficient between the feed screw and nut and other mechanical properties at that position strictly speaking differ. However, in the past, the difference in the rigidity of the members of the feed mechanism and the friction coefficient etc. due to the feed axis position was not considered in numerical control of a machine tool.

The present invention provides, in one aspect, a numerical control method of a machine tool which realizes stable machining precision without regard as to the feed axis position and a numerical control device which conducts that method.

### Solution to Problem

According to the aspect of the invention as set forth in claim **1**, there is provided a numerical control method which controls a feed axis of a machine tool, the numerical control method of a machine tool comprising steps of dividing a range of movement of the feed axis into a plurality of regions and storing in advance a plurality of control parameters corresponding to the divided plurality of regions, analyzing a machining path from a machining program of the machine tool, reading out control parameters corresponding to a divided region determined in accordance with the machining path from the stored plurality of control parameters, and controlling the feed axis using the read control parameters.

Further, according to the aspect of the invention as set forth in claim **2**, there is provided the aspect of the invention as set forth in claim **1**, wherein the control parameters are read out while the feed axis is moving toward a machining start position and are set to the control parameters immediately after reaching the machining start position.

Further, according to the aspect of the invention as set forth in claim **3**, there is provided the aspect of the invention as set forth in claim **1**, wherein, when the machining path extends across a plurality of regions, control parameters corresponding to the region in which the machining path is included the longest are read out.

Further, according to the aspect of the invention as set forth in claim **4**, there is provided the aspect of the invention as set forth in claim **1**, wherein, when the machining path is an arc, control parameters corresponding to the region including a center of the arc are read out. Further, according to the aspect of the invention as set forth in claim **5**, there is provided the aspect of the invention as set forth in claim **1**, wherein the control parameters include at least one of an acceleration/deceleration time constant, feedback gain, feed forward gain, stick motion correction parameter, and filter constant of the feed axis.

Further, according to the aspect of the invention as set forth in claim **6**, there is provided a numerical control device which controls a feed axis of a machine tool, comprising a storage unit which divides a range of movement of the feed axis into a plurality of regions and stores a plurality of control parameters corresponding to the divided plurality of regions, an analysis unit which analyzes a machining path from a machining program of the machine tool, a parameter selection unit which reads out control parameters corresponding to a divided region determined in accordance with the machining path from the stored plurality of control parameters, and a servo control unit which controls the feed axis using the read control parameters.

### Advantageous Effects of Invention

According to the aspects of the invention as set forth in the claims, by dividing the range of movement of the feed axis into a plurality of regions and using a plurality of control parameters which correspond to the divided plurality of regions to control the feed axis, the common effect is exhibited of absorbing differences in the rigidity of the members of the feed mechanism and the friction coefficient etc. due to the feed axis position and realizing stable machining precision without regard as to the feed axis position. Further, the machining program is used as the basis to determine the control parameters in advance, so the effect is exhibited of enabling stable control parameters to be set.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a numerical control machine tool according to one aspect of the present invention.

FIG. **2** is a block diagram which shows a configuration for controlling a Z-axis direction feed mechanism of the numerical control machine tool which is shown in FIG. **1**.

FIG. **3** is a view which shows divided regions and the feed axis positions in the numerical control machine tool which is shown in FIG. **1**.

FIG. **4** is a flow chart of judgment processing which judges if it is necessary to change parameters for stick motion correction of a stick motion correction calculation unit.

FIG. **5** is another flow chart of judgment processing which judges if it is necessary to change the parameters for stick motion correction of a stick motion correction calculation unit.

FIG. **6** is another view which shows divided regions and the feed axis positions.

FIG. **7**A is a first side view of a machine tool.

FIG. **7**B is a view which shows machining error when cutting a workpiece along an arc-shaped path in a machine tool which is shown in FIG. **7**A.

FIG. **8**A is a second side view of a machine tool.

FIG. **8**B is a view which shows machining error when cutting a workpiece along an arc-shaped path in a machine tool which is shown in FIG. **8**A.

FIG. **8**C is a view which shows machining error after correction of stick motion.

## DETAILED DESCRIPTION OF THE INVENTION

Below, referring to the attached drawings, embodiments of the present invention will be explained. In the following figures, similar members will be assigned similar reference notations. To facilitate understanding, these figures are suitably changed in scale.

FIG. **1** is a schematic view of a numerical control machine tool **10** according to one aspect of the present invention. In FIG. **1**, the numerical control machine tool **10** is a so-called horizontal machining center which is provided with a bed **12** which is placed on the floor of a factory etc. On the top surface of the bed **12**, Z-axis guide rails **28** are laid in a horizontal Z-axis direction (left-right direction in FIG. **1**). At the Z-axis guide rails **28**, a table **14** for fastening a workpiece W through a workpiece jig G is slidably attached. FIG. **1** shows an example of fastening an NC rotary table able to rotate in a B-axis direction on the table **14** and placing a workpiece W on top of that, but a workpiece W may be directly placed on the table **14** without interposition of an NC rotary table.

On the top surface of the bed **12**, further, X-axis guide rails **36** are laid in an X-axis direction which is perpendicular to the Z-axis and horizontal (direction vertical to paper surface in FIG. **1**). At the X-axis guide rails **36**, a column **16** is slidably attached. At the front surface of the column **16** facing the workpiece W, Y-axis guide rails **34** are laid in a Y-axis direction, which is perpendicular to the X-axis and Z-axis (in FIG. **1**, top-bottom direction). At the Y-axis guide rails **34**, a spindle head **18** which rotatably supports a spindle **20** is slidably attached.

Inside the bed **12**, at the bottom side of the table **14**, a Z-axis feed screw **24** is laid in the Z-axis direction. At the bottom surface of the table **14**, a nut **26** is fastened which engages with the Z-axis feed screw **24**. At one end of the Z-axis feed screw **24**, a Z-axis feed servo motor Mz is connected. By driving the Z-axis feed servo motor Mz to make the Z-axis feed screw **24** turn, the table **14** moves along the Z-axis guide rails **28**. Similarly, inside the bed **12**, at the bottom side of the column **16**, an X-axis feed screw (not shown) is laid in the X-axis direction. At the bottom surface of the column **16**, a nut (not shown) is fastened which engages with the X-axis feed screw.

At one end of the X-axis feed screw, an X-axis feed servo motor Mx is connected. By driving the X-axis feed servo motor Mx to make the X-axis feed screw turn, the column **16** moves along the X-axis guide rails **36**. Further, inside the column **16**, a Y-axis feed screw **32** is laid in the Y-axis direction. At the back surface of the spindle head **18**, a nut **30** is fastened which engages with the Y-axis feed screw **32**. At the top end of the Y-axis feed screw **32**, a Y-axis feed servo motor My is connected. By driving the Y-axis feed servo motor My to make the Y-axis feed screw **32** turn, the spindle head **18** moves along the Y-axis guide rail **34**.

At the tip of the spindle **20**, a tool **22**, for example, an end mill, is attached. By making the tool **22** rotate while making the column **16**, spindle head **18**, and table **14** operate in the X-axis, Y-axis, and Z-axis directions, respectively, the workpiece W which is fastened to the table **14** is cut to a desired shape. When the NC rotary table is fastened, the numerical control machine tool **10** can be said to be a four-axis numerical control machine tool which has a B-axis.

The numerical control machine tool **10** is provided with a numerical control unit **40** which controls the column **16**, spindle head **18**, and X-axis, Y-axis, and Z-axis feed servo motors Mx, My, and Mz which make the table **14** move in the X-axis, Y-axis, and Z-axis directions. When having an NC rotary table, a B-axis feed servo motor (not shown) is provided.

The numerical control unit **40** includes a program reader/interpreter **44** which reads the NC program **42** and interprets it, an interpreted program storage unit **46** which temporarily stores the interpreted program, a program execution command unit **48** which suitably pulls out a program from the interpreted program storage unit **46** and issues execution program data, a distributed control unit **50** which uses execution program data from the program execution command unit **48** as the basis to issue position command values, speed command values, and acceleration command values to the X-axis, Y-axis, and Z-axis, respectively, and a servo controller **52** which uses the position command values, speed command values, and acceleration command values from the distributed control unit **50** and the later explained feedback signal as the basis to issue torque command values or current command values to a feed axis motor drive unit **54**. Note that, for the B-axis as well, in the same way, the distributed control unit **50** issues position command values, angular speed command values, angular acceleration command values, etc. to the B-axis.

The feed axis motor drive unit **54** uses the torque command values or current command values from the servo controller **52** as the basis to output current and drive the X-axis, Y-axis, and Z-axis feed axis motors (servo motors) Mx, My, and Mz. Further, in the present embodiment, a parameter processing control unit **56** is provided which corrects the torque command values or current command values from the servo controller **52** to the feed axis motor drive unit **54**.

FIG. **2** is a block diagram which shows the configuration for controlling the Z-axis direction feed mechanism of the numerical control machine tool **10** which is shown in FIG. **1**. In FIG. **2**, the components which correspond to FIG. **1** are indicated by the same reference notations.

The servo control unit **52** includes a subtractor **62** which subtracts a position feedback signal S**1** of a Z-axis direction digital linear scale or other position detector Sp from a position command value from a distributed control unit **50** through an acceleration/deceleration control unit **60** for smooth acceleration/deceleration, a position feedback control unit **64** which uses the output of the subtractor **62** as the basis for feedback control of the position, a subtractor **66** which subtracts a speed feedback signal S**2** from a pulse coder PC provided at the feed axis motor M from a speed command which is output from the position feedback control unit **64**, and a speed feedback control unit **68** which uses the output of the subtractor **66** as the basis for feedback control of the speed.

On the other hand, the torque command values, speed command values, and position command values from the distributed control unit **50** through the acceleration/deceleration control unit **60** are sent to a speed feed forward control unit **70**, torque feed forward control unit **72**, speed calculation unit **73**, and acceleration calculation unit **74**. The output values from the speed feed forward control unit **70** are added at the subtractor **66**. Further, the speed value which is calculated at the speed calculation unit **73** is used as the basis to judge if the direction of the speed reverses at a next reversal judgment unit **76**, that is, if the feed direction reverses. If it is judged at the reversal judgment unit **76** that the speed reverses, a stick motion correction calculation unit **78** calculates a stick motion correction value for suppressing stick motion based on the acceleration which is calculated by the acceleration calculation unit **74**, and the stick motion correction value is added at the subtractor **66**. The output value from the torque feed forward control unit **72** and the output value from the speed feedback control unit **68** are added at an adder **80** and the result supplied to a band elimination filter **82**. At the band elimination filter **82**, a filter constant is used as the basis to attenuate the signal of the frequency in a predetermined frequency range and pass signals of other frequencies, then supply them to the feed axis motor drive unit **54**.

The parameter processing unit **56** includes a parameter selection unit **90** and a storage unit **92**. The parameter selection unit **90**, as explained later, has the function of reading the set of the suitable control parameters from the storage unit **92** and using the read values as the basis to change the various types of control parameters. The "control parameters" specifically are the acceleration/deceleration parameter, that is, the time constant, at the acceleration/deceleration control unit **60**, the feedback gain at the position feedback control unit **64** and speed feedback control unit **68**, the feed forward gain at the speed feed forward control unit **70** and torque feed forward control unit **72**, the parameter for stick motion correction at the stick motion correction calculation unit **78**, the filter constant at the band elimination filter **82**, and other vibration suppressing control parameters for motors etc. Note that, the acceleration calculation unit **74**, reversal judgment unit **76**, and stick motion correction calculation unit **78** may also be included in the parameter processing unit **56**. Of course, the parameter processing unit **56** performs other processing as well.

Note that, in the X-axis direction feed mechanism, Y-axis direction feed mechanism, and B-axis direction feed mechanism as well, in the same way as above, position detectors, pulse coders, etc. are provided at the respective feed axis motors etc.

In this regard, as explained above, depending on the feed axis position, the rigidity of the feed screw and the friction coefficient between the feed screw and nut and other mechanical properties at that position strictly speaking differ. According to the present invention, it is possible to stabilize the machining precision without regard as to the feed axis position. Below, the method for that will be explained.

FIG. **3** is a view which shows the divided regions and the feed axis positions in the numerical control machine tool which is shown in FIG. **1**. If the range of movement of the X-axis direction feed axis, that is, in FIG. **1**, the range by which a nut screwed with the not shown X-axis feed screw can move, explained further, the range over which the column **16** can move with respect to the X-axis guide rails **36**, is 0 to X**0**, this range is equally divided into the three regions of the zones X**1**, X**2**, and X**3**. Similarly, if the range of movement of the Y-axis direction feed axis, that is, in FIG. **1**, the range by which a nut screwed with the not 30 shown Y-axis feed screw **32** can move, explained further, the range over which the spindle head **18** can move with respect to the Y-axis guide rails **34**, is 0 to Y**0**, this range is equally divided into the two regions of the zones Y**1** and Y**2**.

Furthermore, FIG. **3** also shows the path of the tool **22**, that is, the planned machining line. First, at the X-axis direction zone X**1** and Y-axis direction zone Y**1**, the workpiece is machined by the machining operation K**1** using P**1** as the machining start position. Then, after movement not accompanied with a machining operation, that is, fast feed movement D, is performed, then a machining operation K**2** is performed from the machining start position P**2**.

To stabilize the machining precision at the time of these machining operations, at each of the divided regions, the optimum values of the time constant and feedback gain and various other types of control parameters are found in advance by experiment and calculation and stored in the storage unit **92**. At the time of machining, the parameter selection unit **90** reads the control parameters corresponding to the region to be machined, that is, the control parameters corresponding to the divided region to which the feed axis position at the time of machining the workpiece belongs, from the storage unit **92** and changes or updates the control parameters at the control unit or calculation unit. The control units or calculation units of the servo control unit are controlled by servo control using the read control parameters for machining.

In relation to this, as the control parameters, the feedback gain of the position feedback control unit **64** is explained as an example. In the X-axis direction feed axis zones X**1**, X**2**, and X**3**, the optimum feedback gains which are stored in the storage unit **92** are designated as the feedback gains FgX**1**, FgX**2**, and FgX**3**. Further, at the Y-axis direction feed axis zones Y**1** and Y**2**, the optimum feedback gains which are stored in the storage unit **92** are respectively designated as the feedback gains FgY**1** and FgY**2**.

The region in which the first machining K**1** is performed is the X-axis direction feed axis zone X**1** and Y-axis direction feed axis zone Y**1**, so due to the parameter selection unit **90**, at the X-axis direction feed mechanism, the current feedback gain is changed to the feedback gain FgX**1** which is read from the storage unit **92**, and, at the Y-axis direction feed mechanism, the current feedback gain is changed to the feedback gain FgY**1** which is read from the storage unit **92** so as to perform the machining operation K**1**. Further, the region where the next machining operation K**2** is performed is the X-axis direction feed axis zone X**3** and Y-axis direction feed axis zone Y**2**, so due to the parameter selection unit **90**, at the X-axis direction feed mechanism, the feedback gain FgX**1** at the time of the end of the machining operation K**1** is changed to the feedback gain FgX**3** which is read from the storage unit **92**, and, at the Y-axis direction feed mechanism, the current feedback gain FgY**1** is changed to the feedback gain FgY**2** which is read from the storage unit **92**.

When the region which is machined extends across several regions, for example, in the case of the machining operation K**3**, which region of values to apply can, for example, be determined by the machining start position. In the case of machining operation K**3**, the machining start position P**3** is present at the X-axis direction zone X**1** and Y-axis direction zone Y**2**, so the control parameters corresponding to that region is applied. Further, the tool path information which was obtained from the interpreted program storage unit **46** may be used as the basis to predict the region with the longest distance machined and apply the control parameters corresponding to the same. In the case of the machining operation K**3**, the region with the longest machining distance is the X-axis direction zone X**2** and Y-axis direction zone Y**2**, so control parameters which correspond to the region may also be applied. Further, control parameters which correspond to the region at the end position of the machining operation may also be applied. Furthermore, insofar as not having an effect on the machining precision, after transition of the region being machined, it is also possible to apply in real time the control parameters which correspond to the region after transition.

Note that, the region to which the parameter selection unit **90** applies the control parameters is specified based on the position command value or position feedback signal S**1** from the distributed control unit **50** through the acceleration/deceleration control unit **60**. Therefore, for example, the position command values from the distributed control unit **50** may be used as the basis to predict in advance and apply control parameters corresponding to the region to which the next machining start position P**2** belongs during the fast feed movement D.

According to the above embodiment, as the control parameters, the feedback gain in the position feedback control unit **64** was explained as an example, but the time constant in the acceleration/deceleration control unit **60**, the feedback grain in the speed feedback control unit **68**, the feed forward gain in the speed feed forward control unit **70** and the torque feed forward control unit **72**, the filter constant in the band elimination filter **82**, the vibration suppressing control parameters in the drive motor, and other control parameters may be similarly applied. In FIG. **2**, the commands shown by the broken line from the parameter selection unit **90** to the acceleration/deceleration control unit **60** are drawn. Similar commands are also sent to the position feedback control unit **64**, speed feed forward control unit **70**, torque feed forward control unit **72**, stick motion correction calculation unit **78**, and band elimination filter **82**, but illustration is omitted.

Regarding the parameters for stick motion correction of the stick motion correction calculation unit **78**, it is necessary to judge each time if it is necessary to change the control parameters, so this will be explained with reference to FIG. **4**. Except for the need for judgment, the method applied when changing the control parameters etc. are similar to that of the feedback gain of the position feedback control unit **64**.

FIG. **4** is a flow chart of judgment processing which judges if it is necessary to change the parameters for stick motion correction of the stick motion correction calculation unit **78**. Referring to FIG. **4**, first, at step **100**, a position command value is acquired from the distributed control unit **50** through the acceleration/deceleration control unit **60**, then the routine proceeds to step **110**. At step **110**, the position command value which is obtained at step **100** is used as the basis to calculate the speed, then the routine proceeds to step **120**. At step **120**, the speed which was calculated at step **110** is used as the basis to judge if the speed has reversed, that is, if the sign has reversed, explained further, if the feed direction has reversed. When, at step **120**, the speed does not reverse, the routine is ended. On the contrary, when, at step **120**, the speed reverses, the routine proceeds to step **130**. Then, at step **130**, the parameter selection unit **90** is used to read out from the storage unit **92** the control parameters of the parameters for stick motion correction corresponding to the region to which the feed axis position belongs, then the routine proceeds to step **140**. At step **140**, the control parameters which were read at step **130** are used as the basis to change the control parameters and the routine is ended.

In the aspect of the present invention explained above, the regions were equally divided, but they may also be not equal. In other words, it is also possible that they differ depending on the location such as being finely divided in places where the fluctuation of the rigidity, friction coefficient, and other mechanical properties with respect to the feed axis position is large and being divided large at places where the fluctuation is small.

Further, in the above-mentioned aspect of the present invention, the storage unit **92** stores independent control parameters for the different feed axis directions. In other words, in the above aspect, the control parameters were the total five of the three in the X-axis direction feed axis and the two in the Y-direction feed axis. Therefore, regardless of the Y-axis direction region, the control parameters corresponding to the X-axis direction region were applied to the X-axis direction feed mechanism. However, control parameters linking the X-axis direction and Y-axis direction may also be stored. That is, in the case of the X-axis direction feed axis zone X**1** and Y-axis direction feed axis zone Y**1**, it is possible to make the feedback gain FgX**1**Y**1**, while in the case of the X-axis direction feed axis zone X**1** and Y-axis direction feed axis zone Y**2**, it is possible to make the feedback gain FgX**1**Y**2**. In this way, it is possible to store six control parameters, that is, the three in the X-axis direction feed axis multiplied with the two in the Y-direction feed axis. By using control parameters which link the X-axis direction and Y-axis direction, it becomes possible to realize more stable machining precision.

Further, in the above-mentioned aspect of the present invention, there were two feed axes, that is, the X-axis direction and Y-axis direction, but there may also be one feed axis or three or more.

FIG. **5** is another flow chart of judgment processing which judges if it is necessary to change the parameters for stick motion correction of the stick motion correction calculation unit. As can be seen from FIG. **5**, it is also possible to determine the control parameters to be changed before actually operating the machine tool. At step **210** of FIG. **5**, the program reader/interpreter **44** reads the NC program **42**, then uses the NC program **42** which is read at step **220** as the basis to analyze the machining path. That is, the program reader/interpreter **44** performs the role as an analysis unit which analyzes the machining path.

Then, at step **230**, it is judged if the machining path is an arc. The program reader/interpreter **44** may also make such a judgment. When it is judged to be an arc, the routine proceeds to step **240**, while when it is not judged to be an arc, the routine proceeds to step **270**. At step **240**, it is judged if the arc-shaped machining path extends across a plurality of zones.

FIG. **6** is another view which shows the divided regions and the feed axis positions. In FIG. **6**, the range **0** to X**0** of possible movement of the column **16** with respect to the X-axis guide rails **36** is divided equally into the three regions of the zones X**1**, X**2**, and X**3**. Similarly, the range **0** to Y**0** of possible movement of the spindle head **18** with respect to the Y-axis guide rails **34** is divided equally into the three regions of the zones Y**1**, Y**2**, and Y**3**.

Furthermore, in FIG. **6**, the arc-shaped machining path K**4** which extends clockwise from the machining start position P**4** and the arc-shaped machining path K**5** which extends from the machining start position P**5** are shown. As can be seen from FIG. **6**, the machining path K**4** extends across a plurality of zones, while the machining path K**5** extends only at one zone (X-axis direction feed axis zone X**3** and Y-axis direction feed axis zone Y**3**).

Again referring to FIG. **5**, when it is judged at step **240** that the arc-shaped machining path extends over a plurality of zones, the parameter selection unit **90** selects control parameters for stick motion correction corresponding to the zone including the center P**4'** of the machining path K**4** (X-axis direction feed axis zone X**2** and Y-axis direction feed axis zone Y**2**). The reason is that when passing through different zones, changing the control parameters is troublesome and time consuming, so setting a single control parameter is advantageous.

Further, when it is not judged that the arc-shaped machining path extends over a plurality of zones, the routine proceeds to step **260**. In this case, as in the machining path K**5** which is shown in FIG. **6**, the machining path extends in only a single zone. At step **260**, the parameter selection unit **90** selects the control parameters for stick motion correction corresponding to the zone including that machining path, in this case, the X-axis direction feed axis zone X**3** and Y-axis direction feed axis zone Y**3**.

In this regard, at step **230**, when it is not judged that the machining path is an arc, at step **270**, it is judged if the machining path extends across a plurality of zones. Further, when the machining path extends across a plurality of zones, the routine proceeds to step **280**.

For example, the machining path K**3** which is shown in FIG. **3** extends across a plurality of zones (X-axis direction feed axis zone X**1** and Y-axis direction feed axis zone Y**2** and X-axis direction feed axis zone X**2** and Y-axis direction feed axis zone Y**2**). At step **280**, the parameter selection unit **90** sets the control parameters for stick motion correction corresponding to the zone including the machining path the most. In the case of the machining path K**3** which is shown in FIG. **3**, the control parameters for stick motion correction corresponding to the X-axis direction feed axis zone X**2** and Y-axis direction feed axis zone Y**2** are set.

On the contrary, when it is judged at step **270** that the machining path does not extend across a plurality of zones, the routine proceeds to step **290**. At step **290**, the parameter selection unit **90** sets control parameters for stick motion correction of the zone including the machining start position. For example, in the case of the machining path K**2** which is shown in FIG. **3**, the control parameters for stick motion correction corresponding to the zone including the machining start position P**2**, that is, the X-axis direction feed axis zone X**3** and Y-axis direction feed axis zone Y**2**, are set.



In this way, in the present invention, the control parameters corresponding to the divided regions which are determined in accordance with the machining path which is analyzed based on the machining program are set. The control parameters are set corresponding to each of the divided plurality of regions. For this reason, in the present invention, it is possible to absorb the differences in rigidity, friction coefficient, etc. of the members of the feed mechanism corresponding to positions of the feed axis and realize stable machining precision without regard as to the feed axis position. Further, various methods of determining which region of control parameters to employ in accordance with the machining path may be considered in addition to the above embodiments. It is also possible to suitably change these in accordance with the workpiece, tool, machining conditions, etc.

Further, in FIG. **6**, in addition to the machining start position P**4**, the movement start position P**0** is shown. In actuality, the feed axis is made to quickly move from the movement start position P**0** to the machining start position P**4**. The parameter selection unit **90** preferably selects the control parameters during the fast feed movement and sets the selected control parameters right after reaching the machining start position P**4**. Due to this, it will be understood that control parameters are set quickly. Further, the control parameters can be determined in advance, so safe control parameters can also be set.

Furthermore, FIG. **7**A is a first side view of a machine tool. As shown in FIG. **7**A, the screw **14***a* of the ball screw and the nut **14***b* which is connected to the table **14** are shown. As is well known, if the motor M is driven, the nut **14***b* moves along the screw **14***a*. In FIG. **7**A, the nut **14***b* is present at a position relatively close to the motor M. The rigidity of the screw **14***a* between the motor M and the nut **14***b* is large. In such a relationship, if cutting the workpiece along the arc-shaped path, as shown in FIG. **7**B, the stick motion becomes relatively small.

On the contrary, as shown in FIG. **8**A, if the nut **14***b* is present at a relatively far position from the motor M, the rigidity of the screw **14***a* between the motor M and the nut **14***b* becomes smaller. Further, in such a relationship, if cutting the workpiece along the arc-shaped path, as shown in FIG. **8**B, the stick motion becomes relatively large.

In the present invention, based on the NC program **42**, the program reader/interpreter **44** analyzes the program and reads the reversal position of the motor M. Further, the control parameters are set as explained above so that torque is added at the reversal position of the motor M (location where stick motion occurs). Further, if using the thus set control parameters for actual machining, as shown in FIG. **8**C, stick motion can be reduced. In other words, in the present invention, by setting in advance the control parameters for stick motion correction, it becomes possible to suppress stick motion which occurs at the time of actual machining.

The invention claimed is:

**1**. A numerical control method which controls a feed axis of a machine tool, which reads and interprets a machining program, issues position commands and speed commands from a distributed control unit to a servo controller, and issues torque commands and current commands to a feed axis motor drive unit on the basis of the position commands and speed commands, said numerical control method of a machine tool comprising steps of:

dividing a range of movement of the feed axis into a plurality of regions and storing in advance a plurality of control parameters corresponding to said divided plurality of regions and used by the servo controller,

analyzing a machining path from the machining program of said machine tool,

reading out control parameters corresponding to a region selected from the divided plurality of regions, determined in accordance with said machining path from said stored plurality of control parameters, the selected region being a region in which the analyzed machine path is the longest, a region in which a center of an arc shape of the analyzed machine path is located, or a region in which a machining start point of the analyzed machine path is located, and

servo controlling the torque commands and current commands to be sent to the feed axis motor drive unit using the read-out control parameters while the read-out control parameters are inputted to the servo controller.

**2**. The numerical control method of a machine tool as set forth in claim **1**, wherein said control parameters are read out while the feed axis is moving toward a machining start position and are set to said control parameters immediately after reaching said machining start position.

**3**. The numerical control method of a machine tool as set forth in claim **1**, wherein said control parameters include at least one of an acceleration/deceleration time constant, feedback gain, feed forward gain, stick motion correction parameters, and filter constant of said feed axis.

**4**. A numerical control device which reads and interprets a machining program, issues position commands and speed commands from a distributed control unit to a servo controller, and issues torque commands and current commands to a feed axis motor drive unit on the basis of the position commands and speed commands so as to control a feed axis of a machine tool, comprising:

a storage unit which divides a range of movement of the feed axis into a plurality of regions and stores a plurality of control parameters corresponding to said divided plurality of regions and used by the servo controller,

an analysis unit which analyzes a machining path from the machining program of said machine tool,

a parameter selection unit which reads out control parameters corresponding to a region selected from the divided plurality of regions, determined in accordance with said machining path from said stored plurality of control parameters, the selected region being a region in which the analyzed machine path is the longest, a region in which a center of an arc shape of the analyzed path is located, or a region in which a machining start point of the analyzed path is located, and

a servo control unit which receives the read-out control parameters and servo controls the torque commands and current commands to be sent to the feed axis motor drive unit using the read-out control parameters.

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